MODIFICATION OF AUSTENITIC CAST IRON (NI-RESIST) WITH HIGH MANGANESE CONTENT BY USING HEAT TREATMENT

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ABSTRAK

Besi Tuangan Austenitic (Ni-resist) digunakan secara meluas dalam industri kimia dan loji kuasa, automotif dan industri minyak dan gas. Bahan ini menawarkan ketidakstabilan sifat yang luar biasa pada suhu yang cukup tinggi dan ketahanan terhadap pengaratan dan hakisan seperti yang dituntut oleh industri. Struktur mikro Austenitic dalam Ni-melawan wujud kerana pengaruh nikel sebagai pemangkin austenitic matrik yang utama. Walau bagaimanapun, menggunakan nikel sebagai aloi tambahan utama untuk pengeluaran Ni-menolak Alloy adalah mahal kerana mempunyai harga yang tidak stabil. Oleh itu, menggunakan mangan sebagai pengganti nikel atau campuran keduanya untuk memangkin matriks austenit adalah pilihan yang boleh diambil kira dalam mengurangkan jumlah kos pemprosesan. Oleh itu, kajian ini bertujuan untuk meneroka kemungkinan untuk mengurangkan penggunaan nikel dengan penggantian mangan untuk menjana struktur austenit Ni-resist. Selain itu, penyiasatan mengenai kesan sifat-sifat ke arah perubahan Ni-resistif (Mn-Ni-resist) sebelum dan selepas rawatan haba adalah menarik untuk dikaji. Bahan besi austenit mangan yang lebih tinggi dengan kandungan nikel yang dikurangkan (Mn-Ni-resist) dihasilkan dengan kandungan mangan 9 wt%, 10 wt%, 11wt% dan 12wt% menggunakan blok Y berdasarkan piawaian ASTM A436 dengan menggunakan acuan pasir hijau . Sampel kemudian dipanaskan pada suhu 700ºC, 800 ºC, 900 ºC, dan 1000 ºC selama 3 jam sebelum perlahan-lahan didinginkan ke suhu bilik dalam suhu relau. Hubungan kompleks antara pembangunan mikrostruktural pemejalan dan membina pemisahan mikro disebabkan peningkatan Mn wt% dalam Mn-Ni-resist diperoleh dengan menggunakan analisis lengkung haba pendinginan dan dibantu dengan pemerhatian mikroskopik dan ujian mekanik. Eksperimen menggambarkan pencirian mikrosegregasi dalam Mn-Ni-resist telah dibuat menggunakan kiraan mikroanalisis di sepanjang mikrostruktur. Hasilnya menunjukkan bahawa penambahan mangan dan rawatan haba mempengaruhi struktur mikro dan sifat mekanik. Lenkung penyejukkan menurun dan morfologi austenit lengan dendrite dilihat memendek sebagai peningkatan Mn wt%. Kemudian, kekuatannya berkurangan dan lebih rendah berbanding dengan besi tuang konvensional. Pemerhatian mikrostruktur menunjukkan bahawa Mn-Ni-resist terdiri daripada serpihan grafit yang tertanam dalam matriks austenitik dan karbida terkumpul di dalam bingkai grafit yang berbentuk roset dimana dikenali juga sebagai rantau membekukan terlambat(LTF). Suhu *annealed* yang lebih tinggi pada Mn-Ni-resist telah berjaya mengurangkan pembentukan karbida dan sedikit meningkatkan kekuatan tegangan. Suhu *annealed* yang lebih tinggi menunjukkan karbida diubah menjadi saiz yang lebih kecil dan menyebar melalui struktur matriks austenit. Saiz karbida menurun dengan peningkatan suhu *annealed* seperti yang diperhatikan dalam struktur mikro. Sebaliknya kekerasan berkurangan apabila suhu annealed bertambah.

ABSTRACT

Austenitic cast iron broadly used in chemical and power plant, automotive and oil and gas industry. This material offers outstanding properties instability at a moderately high temperature and resistance to corrosion and wear which demanded by the industry. Austenitic microstructure in Ni-resist exists due to the influence of nickel as prime austenitic matrix promoter. However, using nickel as prime alloy addition for the production of Ni-resist Alloy is expensive due to its unstable prices. So, employing manganese as nickel replacement or mixing with for austenitic matrix promoter is an option that may reduce total processing cost. Therefore, the present study aims to explore the possibility to reduce nickel consumption by manganese substitution to generate the austenitic structure of Ni-resist. Furthermore, an investigation on the effect of the properties towards modified Ni-resist (Mn-Ni-resist) before and after heat treatment is appealing. Higher manganese austenitic cast iron with reduced nickel content (Mn-Ni-resist) was produced with manganese content nine wt%, ten wt%, 11 wt% and 12 wt% through Y-block according to ASTM A436 by using a green sand mold. Samples were then annealed at 700ºC, 800 ºC, 900 ºC, and 1000ºC for 3 hours before slowly cooled to room temperature in furnace temperature. The complex relationship between the development of the solidification microstructures and build up of micro-segregation due to increasing Mn wt% in Mn-Ni-resist was obtained by using cooling curve thermal analysis and complemented by microscopic observation and mechanical properties. Experimental describe the characterization of microsegregation in Mn-Ni-resist was made using point counting microanalysis along the microstructure. The result showed that manganese addition and heat treatment affect the microstructure and mechanical properties. Solidification cooling curve decreased, and the morphology of austenite dendrite arm shortened as the Mn wt% increased. Then, the strength reduced and more inferior compared to conventional cast iron. Microstructure observations revealed that Mn-Ni-resist consists of flake graphite embedded in the austenitic matrix and the accumulative of carbide at the frame of the rosette flake graphite and also known as late to freeze region (LTF). Higher annealing temperature on the Mn-Ni-resist has successfully reduced carbide formation and slightly increases tensile strength. The higher annealing temperature shows carbide altered into a smaller size and disperses through the austenitic matrix structure. The size of carbide decreased with increasing annealing temperature as observed in the microstructure. On the other hand, hardness diminished as the annealing temperature increases.

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LIST OF SYMBOLS

γ	Austenitic
α	Ferrite Iron
T_{liq}	Liquidus temperature
T_{und}	Undercooling temperature
T_{eut}	Eutectic temperature
T_{end}	End of solidification temperature
dT / dt	1st derivation
T_L	Austenite liquidus temperature
T_E	Equilibrium point of graphite eutectic temperature
T_C	Equilibrium point of carbide eutectic temperature
V	Volume
P	Density
C_p	Heat capacity
Q_L	Heat of solidification
T	Time
H	Convection heat transfer coefficient
A	Area
T	Temperature
D	Diffusion rate of carbon in austenite
R	Nodule size of graphite
S	Distance
X	Molar fraction
K_s	Segregation Coefficient

LIST OF ABBREVIATIONS

T-T-T	Time –temperature-transformation
ASTM	American standard for testing material
ADI	Austempered ductile iron
Ni-resist	Austenitic cast iron
TA	Thermal analysis
DNR	Ductile ni-resist
FCC	Face centered cubic
BCC	Body centered cubic
TAL	Temperature of the liquidus arrest
TES	Temperature of eutectic nucleation
TEU	Temperature of eutectic undercooling
TER	Temperature of eutectic recalescence
TEE	Temperature of the end of eutectic solidification
DTA	Differential thermal analysis
LTF	Last to freeze
DAS	Dendrite arm spacing
SDAS	Secondary dendrite arm spacing
TC	Total carbon
CEV	Carbon equivalent
CAE	Calculation of liquidus value
NiFe	Nickel Ferro
FeMn	Ferromanganese
MgFeSi	Magnesium ferrosilicon
FeSi	Ferrosilicon
SEM	Scanning electron microscopy
EDX	Energy dispersive X-ray spectroscopy
OM	Optical microscope
XRD	X-ray diffraction
kW	Kilowatt
HCL	Hydrochloric
KOH	Kalium hydroxide
NaOH	Natrium hydroxide
HMV	Hardness micro Vickers
HV	Hardness Vickers

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